

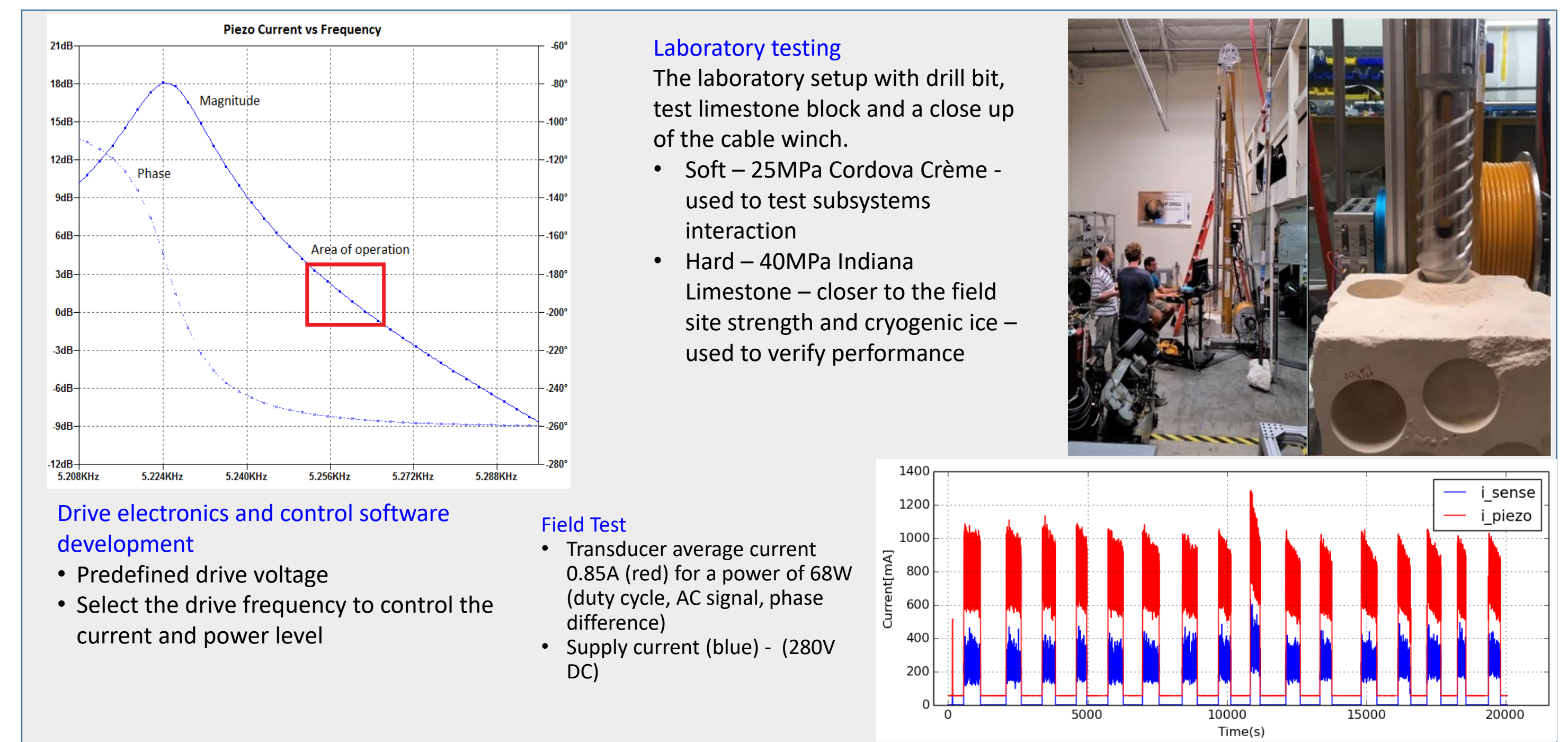
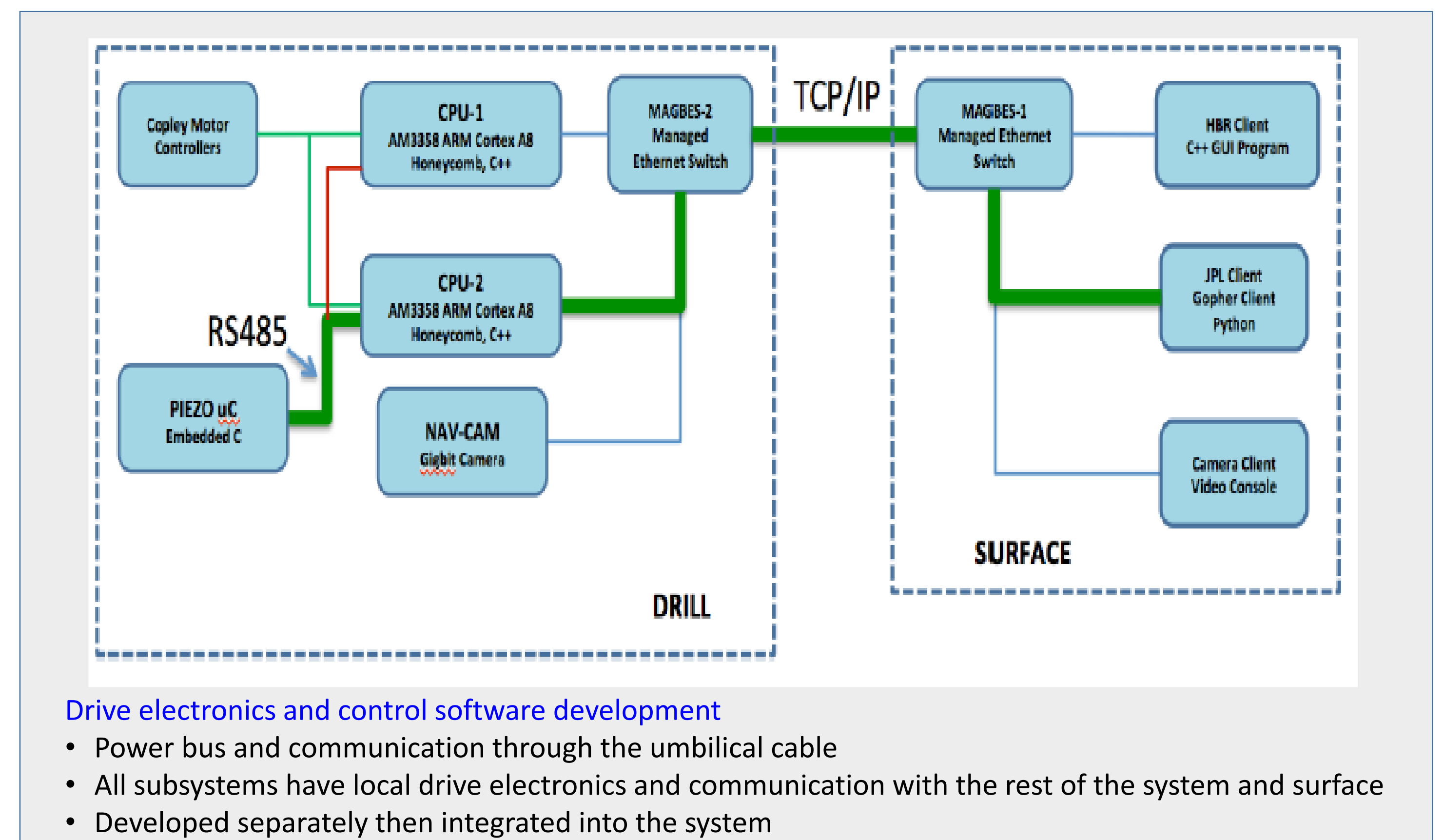
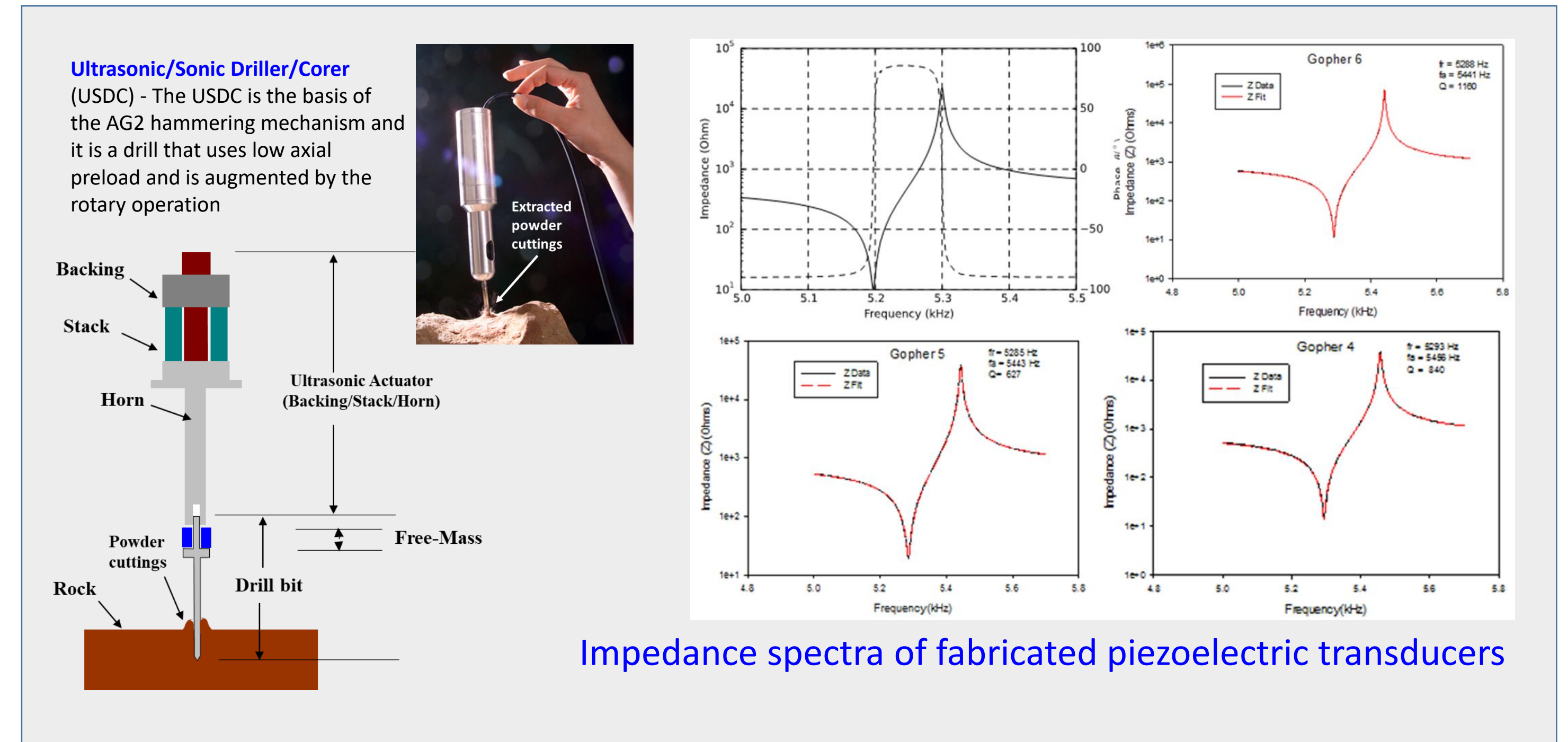
Auto-Gopher-2 (AG2) – Autonomous wireline rotary piezo-percussive drill for deep excavation

Yoseph Bar-Cohen, Mircea Badescu, Stewart Sheritt, Xiaoqi Bao, Hyeong Jae Lee, Shannon Jackson and Brandon Metz
Jet Propulsion Laboratory, California Institute of Technology, (MS 67-119), 4800 Oak Grove Drive, Pasadena, CA 91109,
Phone 818-354-2610, yosi@jpl.nasa.gov, web: <http://ndeaa.jpl.nasa.gov>

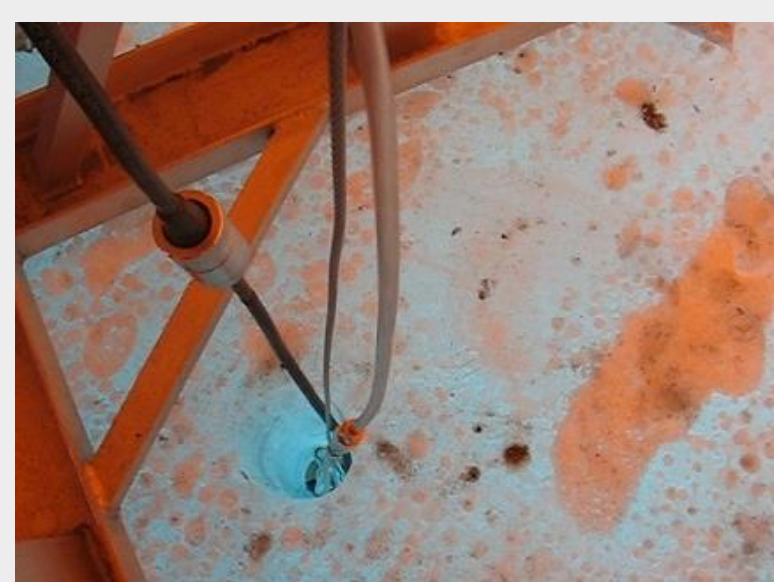
and

Kris Zacny, Bolek Mellerowicz, Daniel Kim, Gale L Paulsen
Honeybee Robotics Spacecraft Mechanisms Corporation, Pasadena, CA

- In order to reach great depths on the moon for human settlement, In-Situ Resource Utilization (ISRU) and construction of infrastructure applications will require effective drilling mechanisms.
- The required drill has to meet mass, volume and energy consumption constraints and conventional technologies are limited in meeting them.
- To address the related challenges, a deep drill, called Auto-Gopher-2 has been developed jointly by the JPL's NDEAA laboratory and Honeybee Robotics Ltd.
- The Auto-Gopher-2 is a wireline rotary piezo-percussive drill that combines breaking formations by hammering using a piezoelectric actuator and removing and collecting the cuttings by rotating a fluted bit.
- The USDC uses an intermediate free-flying mass to convert high frequency vibrations of a piezoelectric transducer horn tip into lower frequency higher impact energy hammering of the drill bit.
- The USDC concept was used in a previous task to develop an Ultrasonic/Sonic Ice Gopher and then integrated into a rotary hammer device to develop the Auto-Gopher-1.
- The lessons learned from these developments were implemented into the development of the Auto-Gopher-2, an autonomous deep wireline drill with integrated cuttings management and drive electronics.
- Subsystems of this wireline drill were developed in parallel at JPL and Honeybee Robotics Ltd.
- The AG2 system was field tested by drilling in a consolidated gypsum formation and reached a depth of 7.52 meters.



Test of the ice-Gopher in Antarctica



The gopher at 176cm deep in Lake Vida



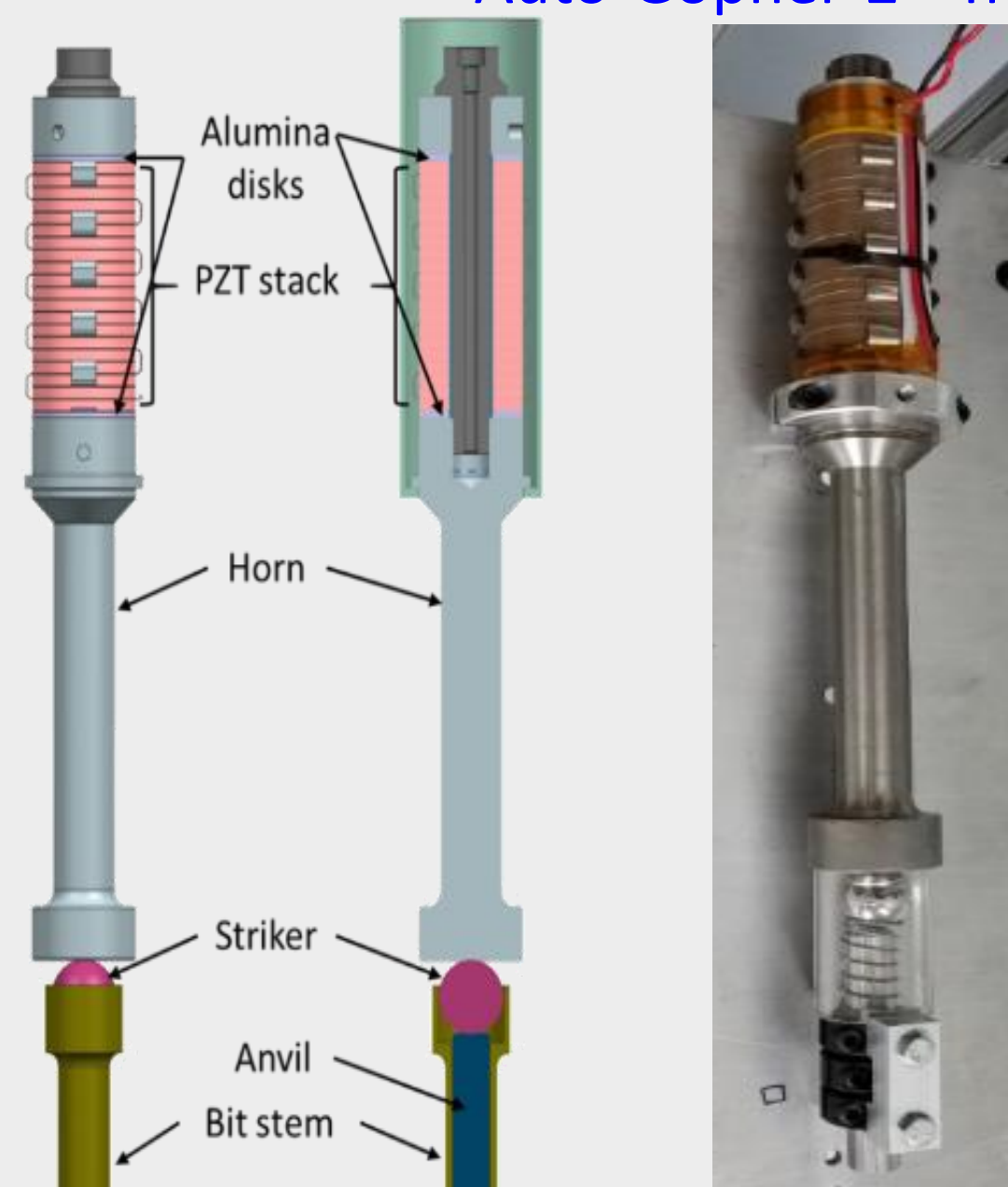
Lake Vida test site

Field test of the Auto-Gopher-1

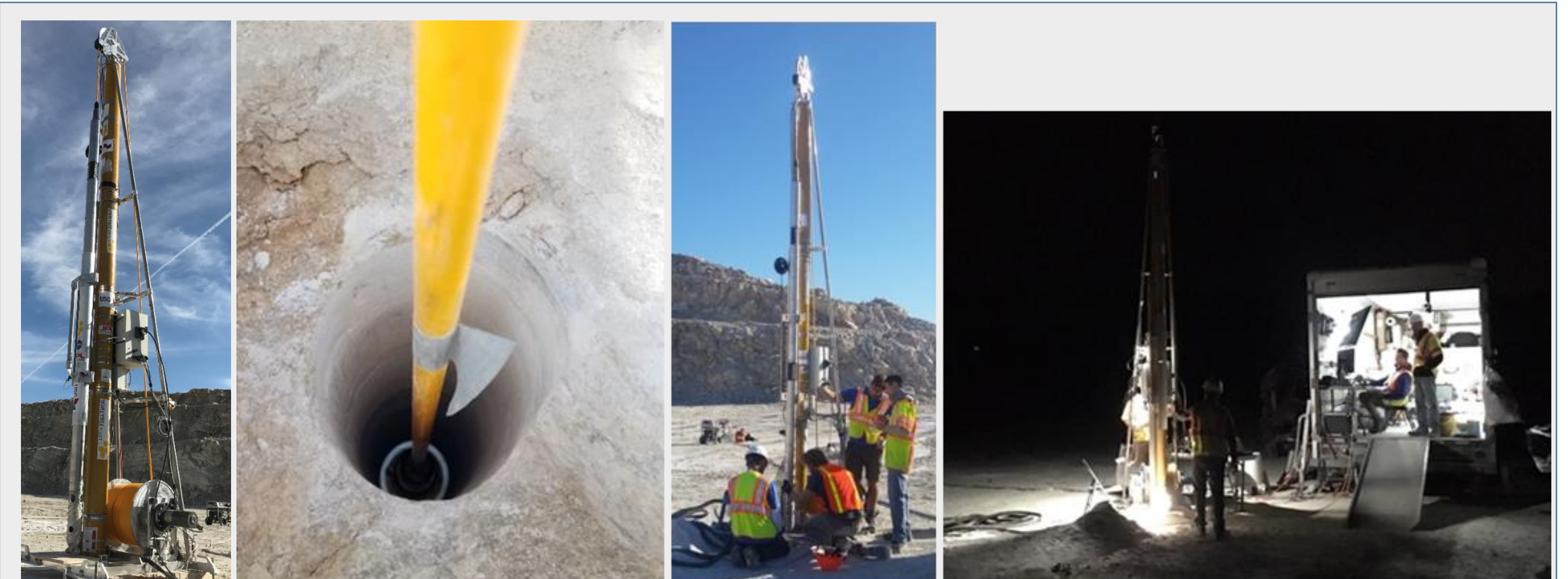
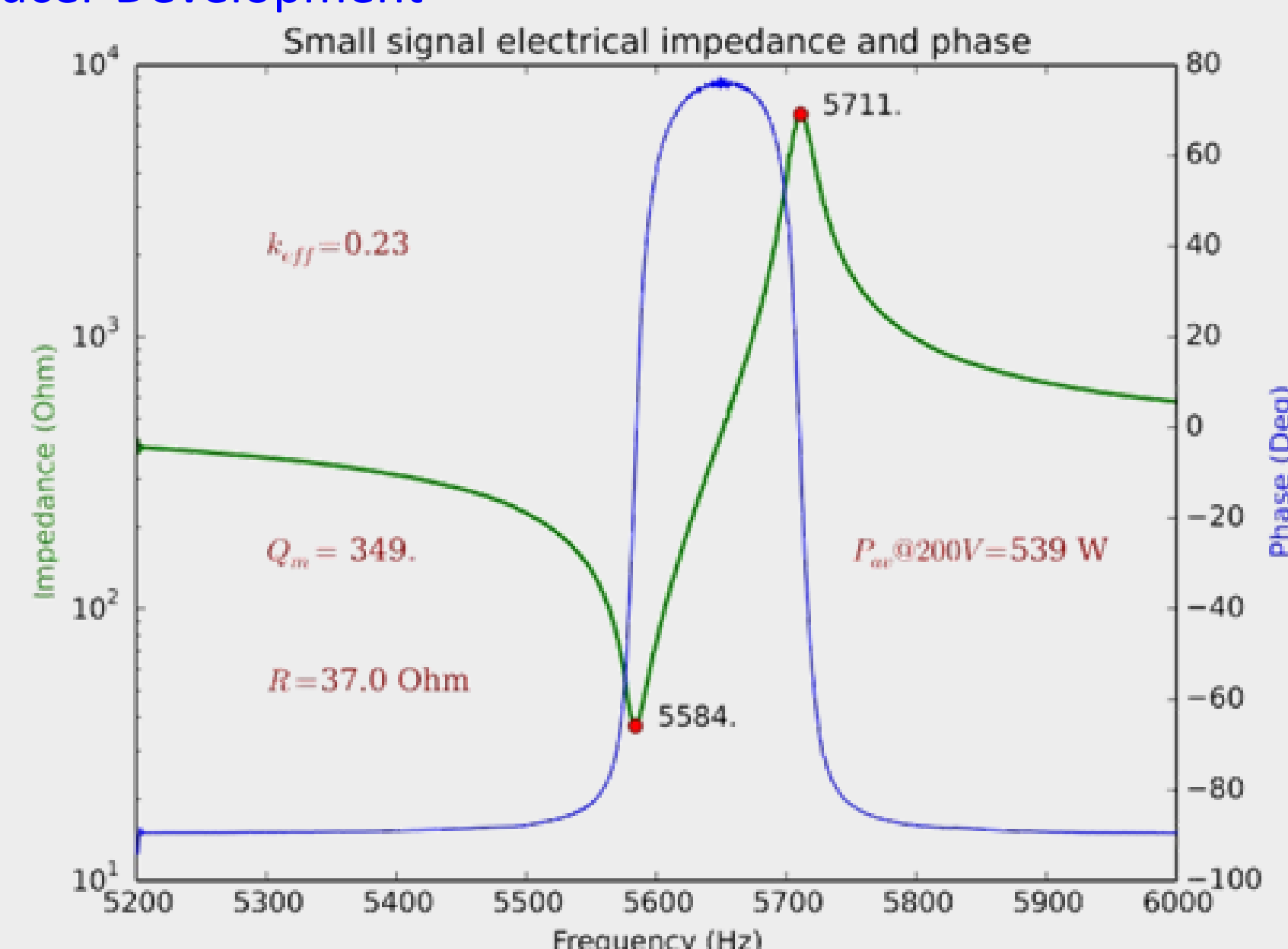


- 32 cores were extracted from a depth of 3.07 meter
- The field trip was performed over three days in November 2012

Auto-Gopher-2 - Transducer Development



Design, components, first fabricated prototype, impedance spectra



Field testing

- Borrego Springs gypsum quarry (US Gypsum Company facility)
- Average rock strength: 39MPa
- Input parameters: Sweep Current 1000mA; Fuse Current 1500mA; Cycle Time ON 2 sec; Cycle Time OFF 1 sec (Duty Cycle 66%).

Conclusions and future work

- With the development of Auto-Gopher-2, we demonstrated a scalable technology that will make deep drilling possible with current launch vehicles, power sources, and entry descent and landing (EDL) systems.
 - Power < 500 W
 - Mass 65 kg
 - Length 3.7m
 - Flight like umbilical cable
 - Drilled 7.52m, more than twice the drill's total length
- Yet to be solved/improved
 - Reduce size (length) and mass
 - Automatic drill bit unloading